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Light alloys and their classification,

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(Le Génie Civil).

The term « light » is applied to those alloys whose density lies between 2 and 3, while by « ultra-light » alloys we understand those of a density less than 2. Alloys having a density greater than 3 are « heavy », and these clearly cover a vast range. Light alloys for industrial purposes are at present composed chiefly of aluminium, and in ultra-light alloys the chief constituent is magnesium.

The writer has, on many occasions heard bodies and representatives of industry complain, with reason, of the bewildering nomenclature of these products, which consists mostly of fantastic names or incomprehensible abbreviations. This criticism is a general one which does not apply to magnesium or aluminium alloys alone.

It is, however, necessary to bear in mind that the constantly increasing complexity of composition of these alloys prohibits any simple appellation which, by the same token, would be erroneous; indeed, there is a great number of combinations of at least five elements. Users of light and ultra-light alloys need a guide which is simple and yet complete. It is here that one realises that this end is not easy of attainment.

The classification adopted, whatever its nature, must permit easy access to the subject or the information which forms the basis of this classification. Now, the user may, according to circumstances, seek the answers to widely differing questions, each calling for a classification to itself, and the difficulties are thus multiplied.

The user may in fact require information concerning :

(1) The properties and the composition of an alloy of known name, in which case there must be an alphabetical classification;

(2) Alloys suitable for casting only or for forging, which possess properties, in particular tensile strength or hardness, corresponding to his requirements. This involves classification in two categories with, for each of these, further classification in order of magnitude of the values for strength or hardness. This will lead to repetition, the same alloy sometimes appearing in both categories;

(3) A given property, such as resistance to corrosion, with chemical composition subsequently to be considered, whence there would arise numerous

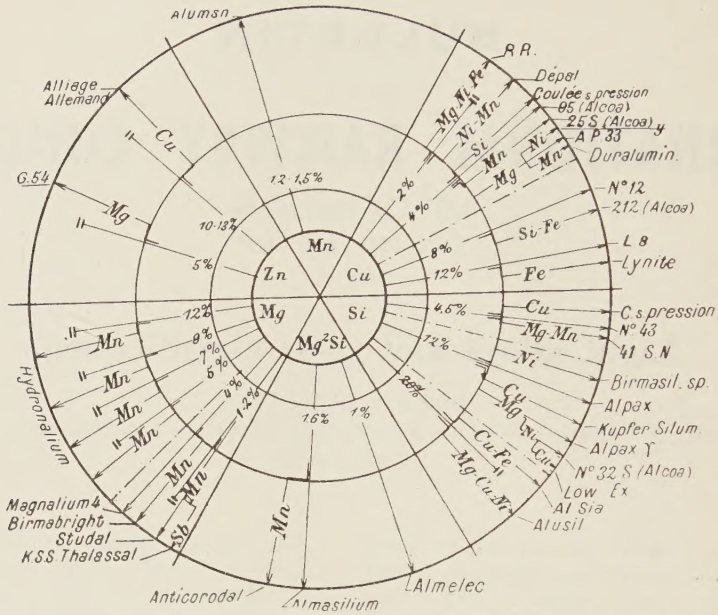

Fig. 1. — Graph showing J. Douchement's classification of light alloys.

Note. — Coulé s. pression, or C. s. pression = pressure-cast.

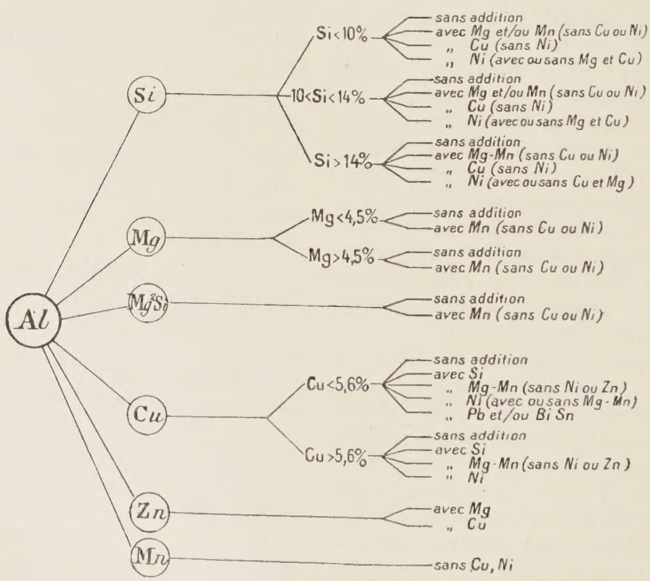

Fig. 2. — Table showing J. Douchement's classification of light alloys.

Note. — Sans addition = without admixture. — Avec Mg et/ou Mn (sans Cu ou Ni) = with Mg and/or Mn (without Cu or Ni). — Sans = without. — Avec ou sans = with or without.

classifications with, furthermore, the attendant possibility of omissions;

(4) Alloys which are simple to use; for instance, without heat treatment. This introduces a new classification.

In connection with the classification of light alloys, Mr. J. DOUCHEMENT has written a most interesting paper (1) wherein he proposes a method which, to the writer, seems the most rational and which is summarised in Figs. 1 and 2.

This method will, to a certain extent, be followed here in order to provide a *classification by chemical family* commencing with the dominant element and reviewing it in the following sequence :

1st FAMILY : *Aluminium-Silicon;*
2nd FAMILY : *Aluminium-Magnesium;*
3rd FAMILY : *Aluminium-Mg^2Si;*
4th FAMILY : *Aluminium-Copper;*
5th FAMILY : *Aluminium-Zinc;*
6th FAMILY : *Aluminium-Manganese.*

The Aluminium-Mg^2Si family is included on account of the part played by Mg^2Si as a hardening constituent.

The writer has been led to make occasional slight exceptions to the general rule where this would otherwise have excluded, for example from Family 1, all alloys containing small quantities of manganese (Family VI), of copper (Family IV), of magnesium (Family II), and similarly in each family with respect to the following ones.

Now, to take an example, the 12, 13 and 20 % silicon alloys chiefly owe their properties to their relatively high content of this element. Manganese, magnesium, copper and titanium play secondary parts only, although certain of these (magnesium and copper) ensure the effectiveness of a heat treatment which, without them, would have only an insignificant effect.

The writer's difficulty is clear; he believes that he has followed a logical course so far as it is possible in a matter such as this.

In what follows there will be given, on the one hand an *alphabetical classification* in order to facilitate search, and on the other a *classification based on utilisation,* whether in the form of castings or of forged or rolled products, with reference to the numbers of the classification *by family.*

We would especially point out that these classifications do not cover *the whole* of the innumerable alloys which have been either described or patented during the past forty years. There are more than five hundred such, and to consider them all would be of little interest. Certain of them have never been prepared, some have never been in normal use, while others have had very brief and unimportant applications and have not been manufactured for a long time past.

The writer has therefore investigated the principal alloys at present in use, not only in France but also abroad. His list is none the less lengthy, since it includes 60 alloys and, it is believed, will meet the needs of all those interested.

Among the many aluminium alloys, there are some which differ among themselves only in respect of very small additions of certain constituents. This has made possible a *simplified classification.*

A manufacturer looking in the following tables for an alloy which shall satisfy some of his requirements, will certainly have the impression that he is in the presence of products obtained by « cookery recipes », as numerous elements seem to have been introduced by more or less happy chance. This is far from being so; few metallurgical questions have been studied more systematically than that of the alloys and particularly, during the last thirty years, the alloys of aluminium.

(1) « Association française des Méthodes d'Essais », 4th June 1937, and *Revue de Métallurgie*, September 1937, page 520.

A. — **Classification of the pri**

Serial number of alloy.	Composition, %.								State.
	Si	Mg	Cu	Zn	Mn	Fe	Ni	Various.	

FIRST FAMIL

Serial number of alloy.	Si	Mg	Cu	Zn	Mn	Fe	Ni	Various.	State.
I-1	5	»	»	»	»	»	»	»	sand cast chill cast
I-2	12-13.5	»	»	»	»	»	»	»	sand cast chill cast
I-3	20-27	»	»	»	»	»	»	»	chill cast
I-4	13	0.3	»	»	0.4	»	»	»	sand cast chill cast
I-5	13	0.3	»	»	0.4	»	»	»	sand cast, annea chill cast, annea sand cast, h.-tre chill cast, h.-tre
I-6	13	»	0.8	»	»	»	»	»	sand cast chill cast
I-7	20	»	1.5	»	»	2.5	»	»	cast
I-8	12	1.25	»	»	2.5	<0.5	»	Ti = 0.25	chill cast, h.-tre
I-9	12	1.25	2.5	»	1.25	<0.5	2.5	Ti = 0.25	chill cast, h.-tre
I-10	14	1	0.9	»	»	1	2.5	»	chill cast
I-11	20-22	1-1.5	0-1.5	»	1-1.5	<0.6	1	»	chill cast, h.-tre

SECOND FAMII

Note. — We have placed in this family
They certainly contain Mg^2Si also and should appear in the

Serial number of alloy.	Si	Mg	Cu	Zn	Mn	Fe	Ni	Various.	State.
II-1	»	2-3	»	»	»	»	»	»	sand cast chill cast
II-2	»	6.5	»	»	»	»	»	»	forged, harden
II-3	<0.75	3	»	»	0.5	»	»	»	rolled, anneal
II-4	<0.75	5	»	»	0.5	»	»	»	rolled, anneal rolled, cold-wor
II-5	<0.75	7	»	»	0.5	»	»	»	rolled, anneal rolled, cold-wor sand cast chill cast
II-6	<0.75	9	»	»	0.5	»	»	»	rolled, anneal rolled, cold-wor
II-7	0.21	12	»	»	0.5	»	»	»	rolled, anneal rolled, cold-wor cast, h.-treat
II-8	0.3-1	2-2.5	»	»	1.2	»	»	Sb <1	chill cast forged, anneal forged, cold-wo

loys by chemical family.

Mechanical properties. T. S.	Elast. lim.	Elong.	Δ	Principal uses.	Current description.
kgr./mm^2 *(tons/in.^{2})*	kgr./mm^2 *(tons/in.^{2})*	%	Brinell		
ninium-silicon.					
14 *(8.9)*	6 *(3.8)*	4	40	castings	Alloy 43 (U. S. A.)
18 *(11.4)*	8 *(5.1)*	3	50	»	»
18 *(11.4)*	8 *(5.1)*	5	55	castings	Alpax, Silumin
21 *(13.3)*	10 *(6.3)*	4	65	»	»
25 *(15.9)*	15 *(9.5)*	0.5	80	»	Hypersilicon
18 *(11.4)*	10 *(6.3)*	3	60	castings	Alpax β, Silumin β
22 *(14.0)*	14 *(8.9)*	2	80	»	»
21 *(13.3)*	13 *(8.3)*	3	70	»	Alpax γ, Silumin γ
27 *(17.1)*	18 *(11.4)*	2	90	»	»
27 *(17.1)*	22 *(14.0)*	3	90	»	»
29 *(18.4)*	24 *(15.2)*	1	100	»	»
8 *(11.4)*	10 *(6.3)*	3.5	60	castings	Copper bearing Alpax
20 *(12.7)*	12 *(7.6)*	2	70	»	
4 *(8.9)*	» »	»	95	pistons	Alsia
20 *(12.7)*	» »	1	125	castings	Central V
22 *(14.0)*	» »	1.5	135	»	Central A
27 *(17.1)*	24 *(15.2)*	1	120	pistons	Low-ex
8 *(11.4)*	» »	1	120	pistons	Alusil KS 280
inium-magnesium.					
lloys containing a little antimony.					
ly, but they are used in the non-heat-treated state.					
2 *(7.6)*	»	6	45	castings	Nural
4 *(8.9)*	»	9	50	castings	»
0 *(25.4)*	»	28	»	rolled sections, plates, forgings	Alumag
3 *(12.7-14.6)*	10-13 *(6.3-8.3)*	20-25	»	profiled plates	Alumag Peraluman Birmabright Duranalium Duralinox B. S. S. Hydronaliums
4 *(19.0-21.6)*	16-20 *(10.2-12.7)*	25-18	65-75		
) *(22.2-25.4)*	30-35 *(19.0-22.9)*	10-6	90-110		
3 *(20.4-22.8)*	19-22 *(12.1-14.0)*	20-28	70-80		
5 *(25.4-28.6)*	35-40 *(22.2-25.4)*	10-6	100-120		
) *(10.2-12.1)*	10-12 *(6.3-7.6)*	2-5	60-65	castings	G 7 or Mg 7
6 *(14.0-22.8)*	12-14 *(7.6-8.9)*	5-10	65-75		
8 *(24.1)*	22 *(14.0)*	20	85	plates, rolled sections	Alumag, Duralinox, B. S. S.
2 *(20.4)*	29 *(18.4)*	11	110		
4 *(25.4-27.9)*	24-28 *(15.2-17.8)*	16-22	95-105	plates, rolled sections	G 12 Hydronalium, Duralinox P
) *(28.6-31.7)*	40-45 *(25.4-28.6)*	6-10	100-120	»	
5 *(19.0-22.2)*	18-22 *(11.4-14.0)*	10-15	90-100	castings	
8 *(11.4)*	12 *(7.6)*	3	65	castings	K. S. S. Thalassal
2 *(12.7-14.0)*	»	18	50-60	plates, rolled sections	
) *(17.8-19.0)*	»	3	70-75	plates, rolled sections	

A. — **Classification of the prin**

Serial number of alloy.	Composition, %. Si	Mg	Cu	Zn	Mn	Fe	Ni	Various.	State.
									THIRD FAMILY
			Note. — A few alloys in the first two families contain a little magnesium an						
III-1	0.5	0.7	»	»	»	<0.3	»	»	wire-drawn, h.-treat
III-2	1.5	0.7	»	»	»	»	»	»	rolled or wire-draw h.-treated rolled, treated, cold-w
III-3	0.5	1-1.5	»	»	»	»	»	Cd=1.5-2	wire-drawn, anneal wire-drawn, cold-wor
III-4	0.8-1.2	0.5-1.2	»	»	0.3-0.8	»	<0.2	»	wire-drawn, anneal wire-drawn, h.-treat wire-drawn, h.-treat cold-worked
III-5	4	1	»	»	1	»	»	»	sand cast, h.-treat chill cast, h.-treat
									FOURTH FAMILY
				Note. — A few alloys in the first family contain a little copp					
IV-1	»	»	3-5	»	»	»	»	»	rolled and h.-trea
IV-2	»	»	8	»	»	»	»	»	sand cast chill cast
IV-3	»	»	12-13	»	»	»	»	»	sand cast chill cast
IV-4	»	»	4.5	»	»	»	»	Ti = 0.4	sand cast, h.-trea
IV-5	0.5-1.5	»	4.5	»	»	»	»	»	wire-drawn, anne wire-drawn, h.-tre
IV-6	0.5-2	»	6-7	»	»	»	»	»	sand cast chill cast
IV-7	1.5-2.5	»	4-4.5	»	»	»	3-4.5	»	sand cast chill cast
IV-8	»	»	2	»	2	»	2	»	sand cast chill cast
IV-9	0.3-0.8	0.3-0.8	3.5-5.5	»	0.3-0.8	»	»	»	rolled or wire-dra annealed h.-trea h.-treated, cold-w
IV-10	»	»	»	»	»	»	»	»	rolled, h.-treat
IV-11	0.4	0.5	10	»	»	»	»	»	chill cast, h.-tre
IV-12	0.8	0.35	14-17	»	»	»	»	»	chill cast
IV-13	?	1.2	4.5	»	0.25	»	»	Cd = 1-2	chill cast
IV-14	2	0.2	4	»	0.6	»	»	Ti = 0.15	sand cast, h.-tre chill cast, h.-tre
IV-15	»	0.5	4.5	»	»	»	»	Ti = 0.4	chill cast, h.-tre
IV-16	»	1.4	4	»	»	»	2	»	sand cast, h.-tre chill cast, h.-tre forged, h.-treat

oys by chemical family (*continued*).

Mechanical properties.				Principal uses.	Current description.
T. S.	Elast. lim.	Elong.	Δ		
kgr./mm² (*tons/in.²*)	kgr./mm² (*tons/in.²*)	%	Brinell		

inium-Mg^2Si.

, and therefore a little Mg^2Si, but this compound plays a minor part.

33 *(21.0)*	26 *(16.5)*	5	85	wires for electric cables	Almélec, Aldrey
25 *(15.9)*	16 *(10.2)*	23	70	profiled plates	Almasilium
40 *(25.4)*	35 *(22.2)*	8	95		
19 *(12.1)*	10 *(6.3)*	20	»	profiled plates	Inalium
27 *(17.1)*	» »	7	»		
14 *(7.6-8.9)*	7-9 *(4.4-5.7)*	24-30	30-35	profiled plates	Anticorodal Polital Vival
34 *(21.6)*	28 *(17.8)*	12	95		
39 *(24.8)*	35 *(22.2)*	4	115		
23 *(14.6)*	12 *(7.6)*	2	75	castings	41 S. M.
26 *(16.5)*	16 *(10.2)*	1	90		

inium-copper.

here it is a constituent of secondary importance only.

22 *(14.0)*	11.5 *7.3)*	8	6.5	plates	195 (U. S. A.)
14 *(8.9)*	8 *(5.1)*	3	60	castings	so-called American alloy
17 *(10.8)*	10 *(6.3)*	3	65		
17 *(10.8)*	15 *(9.5)*	1	85	castings mostly pistons	so-called English alloy
20 *(12.7)*	18 *(11.4)*	2	95		
4 *(19.0-21.6)*	20-22 *(12.7-14.0)*	4-7	90-100	castings	AP 33
2 *(11.4-14.0)*	» »	15-25	50-60	plates and rolled sections	Lautal
2 *(24.1-26.7)*	20-24 *(12.7-15.2)*	15-20	100-120		
16 *(10.2)*	» »	1	65	castings	Nural 30
20 *(12.7)*	» »	2	70		
16 *(10.2)*	» »	1	75	heat resisting parts	Nural 93
16 *(10.2)*	» »	1	80		»
15 *(9.5)*	10 *(6.3)*	2	55	fittings	Dépal
16 *(10.2)*	10 *(6.3)*	3	60		»
3 *(11.4-14.6)*	10-15 *(6.3-9.5)*	16-22	55-60	plates, rolled sections and forgings	Duralumin type : aludur, avional, alférium, fortal, etc.
4 *(25.4-27.9)*	25-30 *(15.9-19.0)*	16-24	100-110		
8 *(28.6-36.8)*	35-50 *(22.2-31.7)*	10-3	120-150		
»	» »	»	»	»	Duralumin ER
28 *(17.8)*	25 *(15.9)*	0.5	130	pistons	Bohnalite
18 *(11.4)*	» »	0.5	150	pistons	Dural 200
20 *(12.7)*	» »	4	75	castings	Aéral
4 *(15.2-21.6)*	18-30 *(11.4-19.0)*	3-1	85-105	castings	Alufont 2
6 *(15.9-22.9)*	22-32 *(14.0-20.3)*	2-1	90-110	»	»
33 *(21.0)*	» »	4-7	100-120	castings, h.-treated	APM W 41
7 *(14.6-17.1)*	18-22 *(11.4-14.0)*	0.3-0.8	90-100	castings, h.-treated	Y alloy
0 *(15.2-19.0)*	20-23 *(12.7-14.6)*	0.5-1.5	95-105		»
2 *(24.1-26.7)*	20-25 *(14.0-19.0)*	16-20	100-120	forgings	«

A. — **Classification of the prin**

Serial number of alloy.	Composition, %.								State.
	Si	Mg	Cu	Zn	Mn	Fe	Ni	Various.	
									FOURTH FAM
IV-17	0.75	0.5	3	»	»	1.5	0.5	Ti = 0.15	sand cast, h.-trea chill cast, h.-trea forged. h.-treate
IV-18	0.50	0.25-1	1.5-3.5	»	»	»	0.5-1.5	Cr = 0.5-1	forged, h.-treate forged, h.-treated cold-wor
IV-19	2.2	0.5	1.3	»	»	1	1.3	Ti = 0.2	sand cast, h.-trea chill cast, h.-trea
IV-20	1.3	1.6	2.3	»	»	1.4	1.3	Ti = 0.1	chill cast, h.-trea
IV-21	0.7	0.8	2	»	»	1.4	1.3	Ti = 0.1	forged, h.-treate
IV-22	1.1	0.25	1.3	»	0.1	1	0.8	Ti = 1.1	forged, cold-work
IV-23	1.2	0.8	2.5	»	»	1.2	1.5	Ce = 0.15	sand cast, h.-trea chill cast
									FIFTH FAMI
									Note. — The binary al
V-1	»	1.5	»	5	»	»	»	»	rolled, h.-treate
V-2	»	»	2-3	10-12	»	»	»	»	sand cast chill cast
V-3	< 0.4	0.2	1.8-2.2	11.5-12.5	»	1.2-1.6	»	»	sand cast, h.-trea chill cast, h.-trea
V-4	1.8-2.2	»	1.8-2.2	11.5-12.5	0.5	< 0.6	»	»	sand cast, h.-trea chill cast, h.-trea
V-5	1-3	»	4-7	4-6	»	< 1.5	»	»	sand cast chill cast
V-6	3.5	»	»	14	»	»	»	Cr = 0.30 Ca = 1	sand cast
									SIXTH FAM
VI-1	»	»	»	»	1.5	»	»	»	rolled or wire-draw annealed rolled or wire-draw cold-worked
VI-2	»	1	»	»	1.25	»	»	»	rolled, wire-drawn annealed rolled, wire-drawn cold-worked

lloys by chemical family *continued*).

T. S. kgr./mm² *(tons/in.²)*	Elast. lim. kgr./mm² *(tons/in.²)*	Elong. %	Δ Brinell	Principal uses.	Current description.
inium-copper (continued).					
-32 *(15.9-20.4)*	22-27 *(14.0-17.1)*	0.5-1	100-120	castings	Duralite
-35 *(17.8-22.2)*	26-30 *(16.5-19.0)*	2-5	110-135	»	»
-47 *(24.1-29.8)*	29-36 *(18.4-22.8)*	18-10	115-140	forgings	»
-40 *(24.1-25.4)*	» »	24-26	»	rolled and forged prod.	Avial
-48 *(29.2-30.5)*	» »	10-22	»	»	»
-27 *(14.6-17.1)*	18-20 *(11.4-12.7)*	2.5-0	70-75	castings	RR 50
-31 *(15.9-19.7)*	20-28 *(12.7-17.8)*	4-1	75-80	»	»
-40 *(20.3-25.4)*	30-32 *(19.0-20.3)*	1-0	130-150	»	RR 53
-45 *(24.8-28.6)*	34-38 *(21.6-24.1)*	10-20	120-160	forgings	RR 56
-45 *(25.4-28.6)*	» »	10-12	115-125	forgings	RR 66
-31 *(19.0-19.7)*	28-31 *(17.8-19.7)*	1-0	130-140	castings	Céralumin
-42 *(22.8-26.7)*	33-38 *(21.0-24.1)*	1	130-140	»	»
minium-zinc.					
no longer in use.					
)-35 *(19.0-22.2)*	» »	4-6	130-140	rolled sections and plates	G 54
2-19 *(7.6-12.1)*	6-9 *(3.8-5.7)*	1-3	50-60	castings	German alloy
4-22 *(8.9-14.0)*	7-10 *(4.4-6.3)*	2-4	60-80	»	»
6-30 *(16.5-19.0)*	23-25 *(14.6-15.9)*	1.5-0.5	100-160	»	Alufont H
9-32 *(18.4-20.3)*	27-30 *(17.1-19.0)*	2.5-1.5	115-125	»	»
2-24 *(14.0-15.2)*	13-15 *(8.3-9.5)*	2.5-3.5	85-95	»	Alufont W
4-27 *(15.2-17.1)*	11-13 *(7.0-8.3)*	3.5-6	90-100	»	»
2-17 *(7.6-10.8)*	» »	2-0.5	60-90	»	Nural 77
3-20 *(8.3-12.7)*	» »	3-0.5	65-100	»	»
25 *(15.9)*	12 *(7.6)*	5	70	«	Cindal
inium-manganese.					
0-12 *(6.3-7.6)*	4.5-6 *(2.9-3.8)*	30-35	25-30	pressings	Aluman
-22 *(11.4-14.0)*	14-18 *(8.9-11.4)*	3-6	50-60	»	»
-20 *(9.5-12.7)*	8-10 *(5.1-6.3)*	16-22	40-45	decoration	Studal
-30 *(15.9-19.0)*	20-23 *(12.7-14.6)*	2-8	70-80	»	»

B. — Classification of the principal alloys of aluminium in alphabetical order of their current names.

NOTE. — The alloys made in France are indicated in italics in the first column.
The numbers in the second column refer to the classification by family. The Roman numerals indicate the family, and the Arabic figures the rank within the family.

Name of alloy	Number of alloy	Manufacturer.	Composition.
Aéral	IV-13	Compagnie franç. des Métaux	Al-Cu (with Mg^{2}Si and Cd)
Alclad	spec. manuf. bi-metal.	Aluminium Co. of America Aluminium Ltd (England)	Duralumin plated with pure aluminium
Aldrey	III-1	Al. Neuhausen (Switzerland) Aldrey-Ring (Germany)	Al-Mg^{2}Si
Alférium	IV-9	Le Creusot (France)	Al-Cu (with Mg^{2}Si)
German alloy	V-2	All countries	Al-Zn (with Cu)
American alloy	IV-2	All countries	Al-Cu
English alloy	IV-3	All countries	Al-Cu
Alloy 43	I-1	U. S. A.	Al-Si
Almasilium	III-2	Sté du Duralumin (France)	Al-Mg^{2}Si
Almélec	III-1	Aluminium français	Al-Mg^{2}Si
Alpax	I-1		Al-Si
Alpax α	I-5		Al-Si (with Mn and Mg)
Copper Alpax	I-6		Al-Si (with Cu)
Alsia	I-7	Alsia (France)	Al-Si (with Cu and Fe)
Aludur.	IV-9	Al. Wirtoschisgen (Germany)	Al-Cu (with Mg^{2}Si and Mn)
Alufont 2.	IV-14	Al. Neuhausen (Switzerland)	Al-Cn (with Mg^{2}Si, Si, Mn and Ti)
Alufont H	V-3		Al-Zn (with Cu, Fe and Mg)
Alufont W	V-4		Al-Zn (with Cu, Si and Mn)
Alumag	II-2 to 6	Tréfil. et Lamin. du Havre	Al-Mg
Aluman	VI-1	Al. Neuhausen (Switzerland)	Al-Mn
Alusit 280	I-11	Alsia (France)	Al-Si (with Cu, Mg and Ni)
Anticorodal	III-4	Al. Neuhausen (Switzerland)	Al-Mg^{2}Si (with Si, Mn and Ni)
A. P. 33	IV-4	Alais, Froges et Camargue	Al-Cu (with Ti)
A. P. M.	IV-15		Al-Cu (with Mg and Ti)
Avial	IV-18	Bidault (France)	Al-Cu (with Mg^{2}Si, Ni and Cr)
Avional	IV-9	Al. Neuhausen (Switzerland)	Al-Cu (with Mg and Mn)
Birmabright	II-4 to 5	Birmingham Al. Castings	Al-Mg (with Mn)
Bohnalite.	IV-11	Bohn Al. (U. S. A.)	Al-Cu (with Mg^{2}Si)
Bondur.	IV-8	W. L. W.-Bonn (Germany)	Al-Cu (with Mg^{2}Si and Mn)
B. S. S.	II-3 to 5	W. L. W.-Bonn (Germany) Karl-Schmidt (Germany)	Al-Mg (with Mn)
195	IV-1	U. S. A.	Al-Cu
Central A.	I-9	Alais, Froges et Camargue	Al-Si (with Mg^{2}Si, Fe, Mn, Ni and Ti)
Central V.	I-8		Al-Si (with Mg, Mn and Ti)
Ceralumin	IV-23	Stone Co. (England)	Al-Cu (with Mg^{2}Si, Ni and Ce)
Cindal	V-6	?	Al-Zn (with Si, Cr and Ca)
Dépal	IV-7	Duval et Poulain (France)	Al-Cu (with Mn and Ni)
Dural 200	IV-12	?	Al-Cu (with Mg^{2}Si)

B. — Classification of the principal alloys of aluminium in alphabetical order of their current names *(continued).*

Name of alloy	Number of alloy	Manufacturer.	Composition.
Duralite	IV-17	S. I. D. A. (Italy)	Al-Cu (with Fe, Mg, Si, Ni and Ti)
Duralinox H.	II-3 to 7	Aluminium français	Al-Mg (with Mn)
Duralumin	IV-9	Sté du Duralumin (France)	Al-Cu (with Mg^2Si and Mn)
Duralumin	IV-9	Dürener Metallwerke (Germany)	Al-Cu (with Mg^2Si and Mn)
Duralumin F.R.	IV-10	Sté du Duralumin (France)	Al-Cu (with Mg^2Si and Mn)
Duranalium	II-3 to 5	Dürener Metallwerke (Germany)	Al-Mg (with Mn)
Fortal	IV-9	Compagnie franç. des Métaux	Al-Cu (with Mg^2Si and Mn)
G 7 and G 12	II-5 and 7	Aluminium français	Al-Mg (with Mn)
G. 54	V-1	Aluminium français	Al-Zn (with Mg)
Hydronalium	II-5 and 7	I. G. Farbenindustrie (Germany)	Al-Mg (with Mn)
Hypersilicon	I-3	All countries	Al-Si
Inalium	III-3	Compagnie franç. des Métaux	Al-Mg^2Si (with Cd)
K. S. 280.	I-11	Karl-Schmidt (Germany)	Al-Si (with Mg, Mn, Cu and Ni)
K. S. S.	II-8	Karl-Schmidt (Germany)	Al-Mg (with Mn, Si and Sb)
Lautal	IV-5	?	Al-Cu (with Si)
Nural	II-1	Aluminiumwerke, Nuremberg	Al-Mg
Nural 77	V-5	Aluminiumwerke, Nuremberg	Al-Zn (with Cu, Si and Fe)
Nural 93	IV-7	Aluminiumwerke, Nuremberg	Al-Cu (with Si and Ni)
Pantal	II-4 to 5	Vereinigte Leichtmetallwerke Verein. Deutsche Metallwerke	Al-Mg (with Mg^2Si, Mn)
Peraluman	II-3	Al. Neuhausen (Switzerland)	Al-Mg (with Mn)
Polital	III-4	Dürener Metallwerke (Germany)	Al-Mg^2Si (with Mn, Fe and Ni)
R. R. 50	IV-19	High-Duty Alloys (England) Delbart (France)	Al-Cu (with Mg^2Si, Fe, Ni and Ti)
R. R. 53	IV-20	High-Duty Alloys (England) Delbart (France)	Al-Cu (with Mg^2Si, Fe, Ni and Ti)
R. R. 56	IV-21	High-Duty Alloys (England) Delbart (France)	Al-Cu (with Mg^2Si, Fe, Ni and Ti)
R. R. 66	IV-22	High-Duty Alloys (England) Delbart (France)	Al-Cu (with Mg^2Si, Fe, Mn, Ni and Ti)
Silumin	I-2	Metallgesellschaft (Germany)	Al-Si
Silumin β	I-4	Metallgesellschaft (Germany)	Al-Si (with Mg^2Si and Mn)
Silumin γ.	I-5	Metallgesellschaft (Germany)	Al-Si (with ?)
41. S. M.	III-5	Alais, Froges et Camargue	Al-Si-Mg^2Si (with Mn)
Studal	VI-2	Société Studal (France)	Al-Mn (with Si)
Thalassal	II-8	Aluminium français	Al-Mg (with Mg^2Si, Mn and Sb)
Vival	III-4	?	Al-Mg^2Si (with Mn and Ni)
Védal	specially manufact. Bi-metal.	Sté du Duralumin (France)	Duralumin plated with pure Al.
W 41	IV-15	Montupet (France)	Al-Cu (with Mn and Ti)
Y.	IV-16	All countries	Al-Cu (with Mg and Ni)

C. — Classification of the principal alloys of aluminium according to their utilisation, and by family.

NOTE. — The numbers in the second column refer back to the classification by family. The Roman numerals indicate the family, and the Arabic figures the rank within the family. In the fourth column, the higher value refers in general to chill-casting.

Name of alloy	Number of alloy	Chief constituents (other than Al)	T. S. kgr./mm² *(tons/in.²)*
		1. Foundry alloys, not heat-treated.	
Alloy 43	I-1	Si	14 (8.9)
Alpax-Silumin	I-2	Si	18-21 *(11.4-13.3)*
Hypersilicon	I-3	Si	25 *(15.9)*
Alpax β-Silumin β. . . .	I-4	Si (Mg-Mn)	18-22 *(11.4-14.0)*
Alsia (Pistons)	I-5	Si (Cu-Fe)	14 *(8.9)*
Copper Alpax	I-6	Si (Cu)	20 *(12.7)*
Nural	II-1	Mg	12-14 *(7.6-8.9)*
G 7 or Mg 7	II-5	Mg (Mn)	16-26 *(10.2-16.5)*
Thalassal, K. S. S. . . .	II-8	Mg (Mn, Si, Sb)	18 *(11.4)*
American alloy	IV-2	Cu	14-17 *(8.9-10.8)*
English alloy	IV-3	Cu	17-20 *(10.8-12.7)*
Nural 30	IV-6	Cu (Ti)	16-20 *(10.2-12.7)*
Nural 93	IV-7	Cu (Si, Ni)	16 *(10.2)*
Dépal	IV-8	Cu (Mn, Ni)	15-16 *(9.5-10.2)*
Aéral	IV-13	Cu (Mg^2Si, Mn, Cd)	20 *(12.7)*
German alloy	V-1	Zn (Cu)	12-22 *(7.6-14.0)*
Cindal	V-6	Zn (Si, Cr, Ca)	25 *(15.9)*
		2. Foundry alloys, heat-treated.	
Alpax γ, Silumin γ . . .	I-5	Si (Mg-Mn)	27-29 *(17.1-18.4)*
Central V.	I-8	Si (Mg, Mn, Ti)	20 *(12.7)*
Alusil, K S 280 (Pistons) .	I-8	Si (Mg, Mn, Cu, Ni)	18 *(11.4)*
Central A.	I-9	Si (Mg, Mn, Cu, Ti, Ni)	22 *(14.0)*
Low-ex (Pistons)	I-10	Si (Mg, Cu, Fe, Ni)	27 *(17.1)*
Hydronalium. . . . . . . Duralinox P G 12	II-7	Mg (Mn, Si)	30-35 *(19.0)*
41. S M.	III-5	Mg^2Si (Si, Mn)	23-26 *(14.6-16.5)*
Bohnalite	IV-11	Cu (Mg^2Si)	28 *(17.8)*
Dural 200.	IV-12	Cu (Mg^2Si)	18 *(11.4)*
Alufont 2	IV-14	Cu (Mg^2Si, Mn, Ti)	24-36 *(15.2-22.9)*
W 41; APM	IV-15	Cu (Mg^2Si, Mn, Ti)	33 *(21.0)*

C. — Classification of the principal alloys of aluminium according to their utilisation, and by family *(continued).*

Name of alloy	Number of alloy	Chief constituents (other than Al)	T. S. kgr./mm² *(tons/in.²)*
		2. Foundry alloys, heat-treated (continued).	
Y	IV-16	Cu (Mg^2Si, Ni)	23-30 *(14.6-19.0)*
Duralite	IV-17	Cu (Mg^2Si, Mn, Fe, Ni, Ti)	25-35 *(15.9-22.2)*
RR 50	IV-19	Cu (Mg^2Si, Fe, Ni, Ti)	25-31 *(15.9-19.7)*
RR 53	IV-20	Cu (Mg^2Si, Fe, Ni, Ti)	32-40 *(20.3-25.4)*
Ceralumin	IV-23	Cu (Mg^2Si, Fe, Ni, Ce)	30-42 *(19.0-26.7)*
Alufont H.	V-3	Zn (Cu, Fe, Mg)	26-32 *(16.5-20.3)*
Alufont W	V-4	Zn (Cu, Si, Mn)	22-27 *(14.0-17.1)*
Nural	V-5	Zn (Cu, Si, Fe)	12-20 *(7.6-12.7)*
		3. Alloys for forging and rolling, not heat-treated.	
Peraluman, B. S. S. . . . Alumag. Duralinox. . . Hydronalium, etc. . . .	II-4 to 6	Mg (Mn)	20-38 *(12.7-24.1)*
Thalassal, K. S. S. . . .	II-8	Mg (Mn, Sb)	20-22 *(12.7-14.0)*
Inalium.	III-3	Mg^2Si (Cd)	19 *(12.1)*
Aluman.	VI-1	Mn	10-12 *(6.3-7.6)*
Studal	VI-2	Mn (Mg)	15-20 *(9.5-12.7)*
		4. Alloys for forging and rolling, heat-treated.	
Alumag.	II-2	Mg	40 *(25.4)*
Almélec, Aldrey.	III-1	Mg^2Si	33 *(21.0)* cold-worked
Almasilium	III-2	Mg^2Si	25 *(15.9)*
Anticorodal	III-4	Mg^2Si (Mn)	34 *(21.6)*
195	IV-1	Cu	22 *(14.0)*
Lautal	IV-5	Cu (Si)	38-42 *(24.1-26.7)*
Duralumin type.	IV-9	Cu (Mg^2Si, Mn)	40-44 *(25.4-27.9)*
Duralumin F. R.	IV-10	Cu (Mg^2Si, Mn)	» »
Y alloy	IV-16	Cu (Mg^2Si, Ni)	38-42 *(24.1-26.7)*
Duralite	IV-17	Cu (Mg^2Si, Mn, Fe, Ni, Ti)	38-40 *(24.1-25.4)*
Avial	IV-18	Cu (Mg^2Si, Fe, Ni, Cr)	38-40 *(24.1-25.4)*
R. R. 56	IV-21	Cu (Mg^2Si, Fe, Ni, Ti)	45 *(28.6)*
R. R. 66	IV-22	Cu (Mg^2Si, Mn, Fe, Ni, Ti)	45 *(28.6)*
G. 54	V-1	Zn (Mg)	30-35 *(19.0-22.2)*
Aluman.	VI-1	Mn	12 *(7.6)*
Studal	VI-2	Mn (Mg)	15 *(9.5)*

D. — Simplified classification of the light alloys.

NOTE. — The numbers in the second column refer back to the classification by family. The Roman numerals indicate the family, and the Arabic figures the rank within the family.

Name of alloy	Number of alloy	Composition.	Principal uses
		1. Alloys with silicon.	
Alpax, Silumin. . .	I-2	12 to 13% Si	castings
Hypersilicon . . .	I-3	20 to 27 % Si	pistons
Alpax or Hypersilicon, with Mg, with Cu, with Fe, with Mn, with Ti, sometimes h-treat.	I-4 to 11	Improved Alpax	castings, pistons
		2. Alloys with magnesium.	
Alumag, Duralinox, Duralium, Peraluman, Hydronaliums, B. S. S.	II-1 to 7	3 to 9 % Mg with or without Mn	plates, rolled sections, forgings
Thalassal, K. S. S. .	II-8	Mg, Mn, Sb	castings, rolled or wire-drawn products
		3. Alloys containing Mg_2Si.	
Almélec, Aldrey . .	III-1	low content	electric cables
Almasilium	III-2	Si = 1.5; Mg = 0.7	
Inalium. Anticorodal, Polital, usw. . . .	III-3 and 4	Si = 0.3 to 1 % Mg = 0.5 to 2 % with Mn = 0.3 to 2 % or Cd = 1.5 to 2 %	plates and rolled sect.
Anticorodal (cast) .	III-4	Si = 1 %; Mg = 0.6 % Mn = 0.7 %	castings
41 S. M.	III-5	Si = 4 %; Mg = 1 % Mn = 1 %	castings
		4. Alloys with copper.	
American and English alloys . . .	IV-2 and 3	Cu = 8 to 13 %	castings, pistons
Dépal	IV-8	Cu = 2 %; Mn = 2 %; Ni = 2 %	fittings
Duralumin type . .	IV-9	Cu=3 to 5 %; Si=0.3 to 1 % Mg = 0.3 to 0.8 %; Mn = 0.5 to 1 %	forgings, rolled sections, heat-treated
Duralumin F. R. . .	IV-10	More Mg and Si than in duralumin, with sometimes 0.3 to 0.5 % Fe.	forgings, rolled sections heat-treated stampings, heat-treated

D. — **Simplified classification of the light alloys** *(continued).*

Name of alloy	Number of alloy	Composition.	Principal uses
		4. Alloys with copper (continued).	
Bohnalite	IV-11	Cu = 10 %; Si = 0.4 % Ng = 0,5 %	pistons
Dural	IV-12	Cu = 14 to 17 %; Si 0.8 %; Mg = 0.35 %	pistons
AP 33	IV-4	Cu, Ti	castings, heat-treated
W 41; A. P. M., Y .	IV-16	Cu = 4; Mg = 1; Ni = 2	castings or forgings, heat-treated
Avial	IV-18	Mg^2Si alloy with Cu, Cr and Ni	rolled, wire-drawn and forged products, heat-treated
RR, various . . .	IV-19 to 22	Mg^2Si alloy with Cu, Ti, Fe and Ni	forged, rolled or cast parts, heat-treated
		5. Alloys with zinc.	
German alloy, Alufont H or W, Nural 77	V-2 to 5	Zn = 10 to 12 %; Cu = 2 % with sometimes Si, Fe or Ti	plates and rolled sections
		6. Alloys with manganese.	
Aluman	VI-1	Mn = 1.5 %	plates and rolled sections
Studal	VI-2	Mn = 1.25; Mg = 1 %	plates and rolled sections

In conclusion the writer wishes, in support of this contention, to put forward a *classification based on the action of the different elements upon aluminium.* It is clearly understood that this will be open to some criticism : it is not entirely complete, and the same element may react in different ways, according to its percentage; moreover, it is not at all certain that an element will behave in identically the same fashion in a simple alloy as in a complex one. The writer believes however, that the classification is truly scientific and that it throws light upon the essentials of the subject.

Speaking generally, an element introduced into a metal or into one of its alloys may :

(1) Retain its characteristics;

(2) Form a solid solution with the metal or one of the existing constituents;

(3) Enter into more or less complex combination with the metal or one of the phases of the alloy.

It is quite evident that, according to the percentage to which it is present, the element may behave in several ways, even simultaneously. For example, it may enter into solid solution in a certain proportion, beyond which it will form a combination.

The classification employed here is well known. The writer has himself

used it in the study of the special brasses. In the present case, we have to deal with the question of « structural » hardening (precipitation hardening), the importance of which, especially in the light alloys, appears to form the very justification of a scientific classification.

E. — Classification of the elements in light alloys according to their action.

I. ELEMENTS WHICH DO NOT CAUSE PRECIPITATION HARDENING :

(a) *Element retaining its characteristics in its binary alloys :*

Silicon (at and above 0.05 %).

(b) *Elements forming a solid solution in binary alloys :*

Copper (up to about 0.3 %).
Magnesium (up to about 2 %).
Zinc (up to 2 % maximum).
Titanium (up to 0.02 %).

(It will be seen how narrow is the range of solid solutions in aluminium. The limit given here is that for room temperature, after very slow cooling. This limit rises with the temperature, and it is this which makes precipitation hardening possible).

The formation of a solid solution increases the tensile strength and elastic limit, without necessarily having any detrimental effect on the elongation and the resiliency; the homogeneous solid solution connotes high chemical resistance.

(c) *Elements forming a compound in binary alloys :*

Copper (at and above 0.3 % approx.).
Manganese (at and above 2 % approx.).
Zinc (at and above 2 % approx.).
Iron.
Nickel.
Cerium.
Titanium (at and above 0.02 % approx.).

The formation of a compound increases the hardness, frequently also the hardness at elevated temperatures and the brittleness, but mostly reduces chemical resistance.

II. ELEMENTS WHICH CAUSE PRECIPITATION HARDENING :

(a) *Elements causing a binary compound of aluminium to pass into solution :*

Copper, by forming Al^2Cu.
Magnesium, by forming Al^3Mg^3.
Zinc, by forming Zn^2Al^3 (?).

(b) *Elements causing a complex compound of aluminium to pass into solution :*

Copper and magnesium,
by forming $Al^5Cu^2Mg^2$
(Petrov, case of duralumin).

(c) *Elements causing a binary compound free from aluminium, to pass into solution :*

Magnesium and silicon, by forming Mg^2Si.
Lithium and silicon, by forming Li^2Si^3.

All these elements take effect as a result of quenching and tempering [1]. The writer would stress the following points :

1. In a ternary or a complex alloy, an element may behave otherwise than in a binary alloy. Thus, silicon in the presence of magnesium passes partially, at least, into the form Mg^2Si.

2. The phenomenon of precipitation hardening may be influenced by the presence of certain elements. Petrov has shown that iron prevents the hardening of aluminium-copper alloys by forming the compound Al^7Cu^2Fe.

Consequently this classification does not permit the question to be surveyed in all its complexity, but it throws light upon the general classification.

[1] See *Génie Civil*, 26th November and 3rd December, 1938, pp. 446 and 469.

[625 .23]

Reduction of noise in railway rolling stock,

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(Revue Générale des Chemins de fer.)

INTRODUCTION.

At high speeds railway rolling stock gives rise to a considerable amount of noise. The trouble has become especially noticeable since the fast trains have been almost entirely made up of all-metal vehicles.

Investigation into how to eliminate noise has thus become necessary and is, at the present moment, one of the technical subjects most actively followed up by the chief railway administrations.

The present communication describes what has been done in France to reduce the noise in railway rolling stock.

We shall commence by stating the fundamental definitions of the acoustics of noise; this will be followed by an enumeration of the different methods employed to measure noise and the results of the experiments made in the laboratory, as well as those carried out on the rolling stock itself.

We have, during the investigations, taken advantage of the results already obtained in the endeavour to reduce noise in aeroplane cabins (1).

In France the Alsace-Lorraine System was the first, in 1932, to take effective precautions against noise when constructing its new A8yfi steel carriages, and later the Nord (2) during the 1935-1936 winter, undertook a long series of experiments, more particularly to reduce the noise passing through the floor of its existing steel stock. Finally, since January 1936, the State Railways have conducted systematic researches into the general question of noise reduction in vehicles.

We give, in the present article, the results of the experiments made in the French State Railways laboratory and the results obtained in practice by the various Railway Systems with sound-proofed vehicles.

FIRST PART.

GENERAL.

The problem of the elimination of noise involves that of measuring it. An engineer who, with a view to building less noisy rolling stock, wishes to make

(1) « The reduction of noise in aeroplane cabins », by P. R. Basset and S. J. Zand. *Aeronautical Engineering*, 1934.

(2) Mr. David, Divisional Rolling Stock Inspector of the French National Railways Company, Northern Area, has made a detailed study of the sound proofing materials used in the construction of carriage floors.

systematic tests, must be able to express numerically the results obtained.

Measuring a noise means measuring the intensity of an acoustic sensation. It has, however, hitherto been impossible to establish a relationship between acoustic sensation and the physical characteristics of noise. In order to simplify the matter, it is customary to consider pure sounds when treating acoustic problems, that is sounds corresponding to sinusoidal vibrations, or sounds formed by the superposition of some pure sounds. These are, in fact, the only cases for which we are able to give simple definitions of constants characterising such sounds, and for which exact measurements and calculations can be made.

When noises are involved corresponding to vibrations so complex that they can no longer be decomposed into sinusoidal movements, either experimentally or by calculation, it is impossible to lay down simple definitions and measure the principal characteristics.

What interests us in the investigations which have been made is not the physical characteristics of noise but the physiological ones, which, for a given individual, depend on factors which are little known and vary from one person to another. It is therefore unnecessary to require such investigations to be as exact as those of physics, and we have to proceed by approximation and comparison.

From this we get two kinds of noise investigation and measurement :

1. Objective investigations, made with the aid of apparatus measuring the physical characteristics and taking no account of physiological sensation;

2. Subjective investigations, using appliances which employ the ear as organ of comparison.

Objective investigations allow of a physical study being made of the phenomenon of sound, but it is the subjective ones which permit us to appreciate the progress achieved. The results obtained by the first method have therefore to be interpreted in the light of those derived from the second.

To define a sound, as a measurable quantity, it is necessary to start with some fundamental hypotheses and relations of acoustics.

From the physical point of view, the intensity I of a sound wave propagated through air is defined by the power conveyed by a plane wave of unit section in which the displacement of an abscissa particle x is represented respecting time t by :

$$X = X_0 \sin 2\pi \left(\frac{t}{T} - \frac{x}{L}\right)$$

T being the period and L the wave length.

This intensity is given by the formula :

$$I = \frac{1}{2} \frac{\overline{\Delta p_m}^{2}\xi}{p\gamma}$$

wherein Δp_m is the maximum over-pressure of the wave

$$\Delta p_m = \frac{2\pi E X_0}{L}$$

γ the ratio of specific heats for perfect gases, p the pressure, $\xi = \sqrt{\frac{E}{\rho}}$ the rate of propagation with $E = \gamma p$, the volumetric modulus of elasticity, and γ, the specific mass of the medium (¹).

As with all our sensations, auditive sensation is a result of certain nerve terminations being excited and transmitting the effect received by them to the brain: physiological acoustics, which investigate the mechanism of hearing, seek to establish quantitive relations be-

(¹) The acoustic intensity is equally proportional to the square of the amplitude of the wave X_0 and to that of the frequency $\frac{1}{T}$

$$I = \frac{1}{2} \frac{4\pi^2 E X_0^2}{\xi T^2}$$

tween the sensation of sound and its physical characteristics; such knowledge is indeed indispensable to the establishment of rational methods of noise measurement.

Auditive sensations have certain defined limits, the upper limit of audible frequencies being between 15 000 and 18 000 p. p. s. and the lower one in the region of 16 p. p. s. The ear also has limits as regards intensity; for a given frequency the ear only perceives a sound if its intensity exceeds a certain value called the *fringe of audibility.* Between the minimum sound audible at 1 000 p. p. s. and that producing a painful effect the over-pressure varies in the ratio of 1 to 10^6 and, in consequence, the acoustic intensity varies in the ratio of 1 to 10^{12}.

The very great amplitude of the energy values which the ear is susceptible of perceiving is not surprising when the approximate law of Fechner is stated. This lays down that sensation increases as the logarithm of excitation. The relative increases are what matters to the ear; if a sound increases by 20 % of its value, the sensation of change is about the same, whatever may be the acoustic intensity. One is thus led to express the level of acoustic sensation by the logarithm of the acoustic intensity; consequently the difference of the acoustic sensations S is expressed by the logarithm of the ratio of the sound energies I and I_o, i.e. :

$$S = \log_{10} \frac{I}{I_o} = 2 \log \frac{p}{p_0} \text{ bels.}$$

The decibel.

To avoid having to use fractional numbers the unit called the *decibel* (dbl), i.e. the tenth of a bel, is usually employed, and we have :

$$S = 20 \log \frac{p}{p_0} \text{ decibels.}$$

According to what has been stated above an alteration of 26 % in the intensity of a sound changes its level by 1 decibel. It is convenient to take a certain sound intensity as a reference figure so as to be able always to express differences in sensation starting from a fixed basic value, the fringe of audibility, for example. The American Standard Association, and also the last Congress of Acoustics in Paris, recently adopted as a reference level an intensity of 10^{-16} watts, [at O°C. (32° F.) and 760 mm. (29 7/8 in.) pressure] for a sound of 1 000 p.p.s. The acoustic pressure corresponding to this intensity at an atmospheric pressure H and absolute temperature T is :

$$p = 0.207 \sqrt{\frac{H}{760}\sqrt{\frac{273}{T}}} \text{ millibarye } (^1).$$

The phon.

It appears difficult to establish a correlation between sound sensation and acoustic pressure; the frequency and the sound overpressure must be arrived at accurately in each case. Fletcher and Munson have plotted experimentally curves which give the same degrees of sensation corresponding to 10, 20..., 120 dbl, above the fringe of audibility of a sound of 1 000 p. p. s. (fig. 1). These curves show that the sensitiveness of the ear is weak in the case of deep tone sounds and that the relative sensitiveness for low frequencies increases as the intensity rises. These observations show that the determination of sound pressure by means of a device using objective measurements, in which it is sought to state the sensitiveness independently of the frequency, in no way corresponds with any subjective measurement. It is therefore necessary clearly to define the

(1) In the old American and English reference levels the sound intensity used as a reference is that corresponding to a pressure of 1 millibarye (1 millidyne/cm²). The old figures are thus lower than the new by 13.7 dbl.

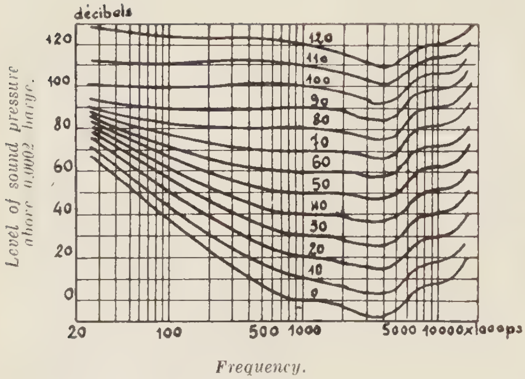


Fig. 1. — Curves of equal acoustic sensation : Curve O corresponds to the fringe of audibility; curve 120 to the fringe of painful sensation.

sense of the term *decibel:* as regards the physiological intensity of a sound of a frequency of 1 000 p. p. s., there is no difficulty, but if it is a question of a sound of another frequency two points have to be distinguished : When measuring the intensity of a sound it is compared with one of 1 000 p. p. s. and when the auditive sensations appear equivalent, the number of decibels corresponding to that of a sound of 1 000 p. p. s. producing the same sensation is adopted to express the intensity. It is thus useful to employ two different words to express these two properties :

(*a*) the *decibel* will represent the difference of level of a sound of a *given frequency;*

(*b*) the *phon* will indicate the value of the intensity of a sound producing the same sensation as one of 1 000 p. p. s.

It is thus seen that considerable difficulties are encountered in making the measurement of sound sensation correspond with the physical constants of a pure sound; it is easy to understand that the problem is still more difficult in the case of a complex sound such as a noise. Experience shows indeed that Fechner's law is inapplicable to the addition of sounds of different frequencies. Fletcher and Munson found that when two sounds of different frequency but of the same intensity were emitted simultaneously, the increase in sensation is not constant and depends on the frequency of the added sound and its initial intensity. They thus determined the curve of excitation as a function of the physiological intensity (fig. 2). It is therefore necessary to know the intensity in phons of each simple sound contained in a noise before deducing therefrom, in

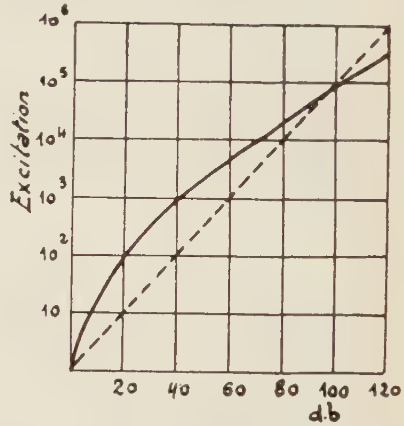


Fig. 2. — Relation between excitation and audibility. Full line, according to Fletcher and Munson; dotted line, $S = 20 \log p$.

accordance with the curve in fig. 2, the value of each excitation and, by an inverse process, the intensity of a noise in phons is determined from the total excitation.

This principle proves defective, however, in certain instances owing to the proximity of the two important frequencies and masking effects. In the case of a noise, the interpretation of auditive sensation by physical measurements is thus very difficult, and it would be illusory to believe there could be much precision in such an interpretation. In investigating noises, therefore, we shall be content to note what objective devices give, calibrated in *decibels,* above the fringe of 0.207 millibarye, on the one hand, and, on the other, what is given

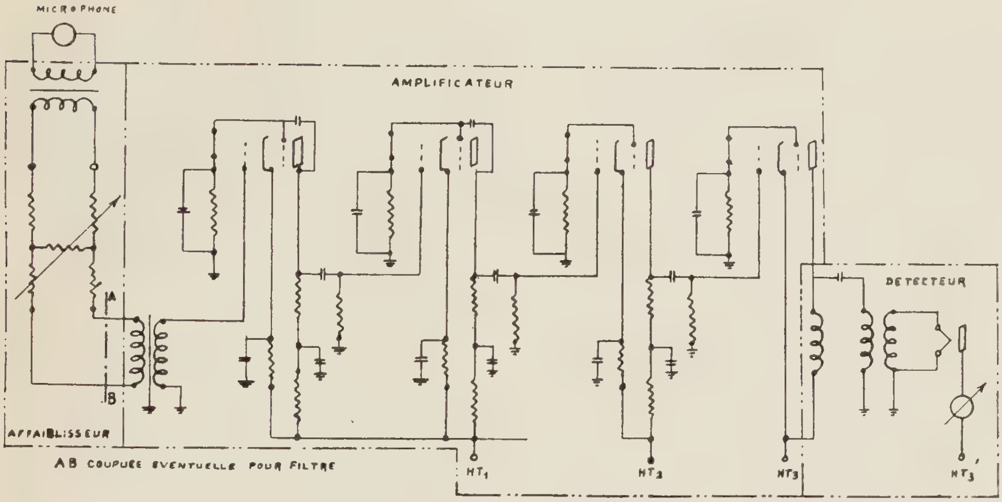


Fig. 3. — Noise measuring apparatus.

Explanation of French terms:

Amplificateur = amplifier. — Affaiblisseur = diminisher. — AB coupure... = AB, connecting points for possible addition of filter. — Detecteur = detector.

by the appliances — in which the ear plays the part of an organ of comparison — graduated in *phons*, above the fringe of 0.207 millibarye at 1 000 p. p. s.

1. *Appliances giving objective measurements.*

With these devices it is sought to express the mean sound over-pressure as an absolute value in decibels above the 0.207 millibarye fringe.

It must be noted that the scale of pressures to be measured extends from 0.2×10^{-3} to 10^{3} millibaryes. The old processes invented for the purpose of measuring sound pressure (Rayleigh's disc etc.), only give results in the case of vibrations of low frequency and large amplitude. They are no longer used, being superseded by *sonometers* (sound meters).

Generally speaking a sonometer consists of (fig. 3):

(*a*) a high-quality microphone transforming sound energy into electric energy;

(*b*) an attenuator, allowing of the electric current being weakened exponentially, varying between 1 and 10^{10};

(*c*) an amplifier, followed by a rectifier;

(*d*) an indicating or recording instrument (milliammeter), graduated in *decibels.*

In practice the milliammeter serves as a zero device and the attenuator reduces the current to be measured to a fixed value. The sonometer [1] is often supplemented by a sound analyser formed of a chain of electric filters, making it possible to measure only those sounds whose frequency is within a certain range; it can likewise include filters reducing the sounds in a ratio equal to the sensitiveness of the ear. Certain other devices determine the frequency of the most important sounds, producing pulsations by means of a heterodyne of variable frequency, but in the case of variable noises, such as

(1) The sonometer used by the State Railway System was made by « Le Matériel Téléphonique » and comprises 8 band filters. The time constant of the recorder is 0.5 second instead of the 0.2 generally allowed, but is sufficient, however, for railway purposes. That used by the O. E. C. M. is of « General Radio » type and has four ear filters.

those met with on railways, this process appears very difficult to apply and has only recently been tried experimentally in Italy.

2. *Appliances for subjective measurements.*

These appliances give, not a measurement, but a register or location of auditive sensation, which appliances for objective measurement are incapable of providing.

They are calibrated in *phons,* above the fringe of audibility of the sound of 1 000 p. p. s. The auditive sensation of the standard sound is compared with the noise being investigated and the number of phons resulting from the comparison attributed to it. These appliances (1) always include a device for producing sound of variable and measurable intensity. Two methods may be employed :

(*a*) The *equalisation method,* consisting in applying the listening apparatus to one ear, the other listening to the noise to be measured, the intensity of the sound emitted being regulated until it appears to be the same as that of the one to be measured. The number indicated by the apparatus is then read off, but the precision thus obtained hardly exceeds 6 to 8 phons.

(*b*) The *masking method,* based on the « mask effect ». This consists in the fact that a weak sound (masked sound) can become inaudible in the presence of a strong one (masking sound). Consequently the presence of the masking sound has the effect of raising the fringe of audibility of the masked sound. To make use of this effect the remote listening device method is used. In this the observer listens simultaneously with one ear to the noise to be measured and to a reference sound of adjustable intensity, heard in a telephonic receiver kept at a certain distance from the ear. Experience obtained with this apparatus has shown us that the difference between the numbers arrived at by different observers does not exceed 2 to 3 phons.

The combination of the appliances using the objective and the subjective methods of measurement forms the noise measuring equipment, the employment of which on the railways is of recent date. The Eastern, Northern and Western Areas of the French National Railways Company's System have been the first to apply these devices to measuring noises in rolling stock.

The problem of sound-proofing.

The degree of comfort afforded by railway rolling stock from the point of view of noise is instinctively judged by the ease with which two persons can hold a conversation without having to raise their voice or make any sustained effort to hear what is being said. The sound intensity of an ordinary conversation is considered to be 60 phons; as conversation already becomes tiring in a noise when it reaches 85 phons, it may be considered satisfactory if the noise can be reduced to a little more than 65 phons (2).

To improve the degree of comfort from the point of view of noise, an endeavour must first be made to reduce the more intense noises; no purpose whatever is served by eliminating a weak noise which is completely masked by a much louder one, the latter alone being heard. If, for example, two noises differ by 10 phons the suppression of the weaker will only reduce the sound intensity by 0.4 phon and the ear will fail to notice such a small improvement, which may have cost much to achieve. Similarly if the two noises are equal it is essential to deal with both at the same time, for to reduce one and not the other would only lower the sound

(1) The French railways possess 5 of these made by « Le Matériel Téléphonique ».

(2) The best result was obtained in the State Railways test carriage when an average noise intensity of 58 phons was measured in a compartment.

intensity by 3 phons, which is hardly noticeable.

Noises in a railway compartment come from:

(*a*) sources inside the vehicle;

(*b*) external sources, propagation taking place through the air;

(*c*) external sources, propagation taking place through solids, that is through the frame members and the walls;

Sources inside the vehicle can only be opposed by acting directly on them, as, for example, in modifying on the spot noisy mechanical devices, such as sliding doors. Investigations into « mechanical sound-proofing » are therefore only made on the stock itself, and it suffices to note during running how the different fittings capable of vibration behave.

On the other hand, there is an advantage in investigating in a laboratory the transmission of noises through the air and through solid materials, for the following reasons:—

(*a*) because these are methods of noise transmission commonly met with and investigations into them can be applied directly, whatever the kind of stock to be made sound-proof;

(*b*) because the number of comparative experiments that would need to be made on a given lot of stock would be too great and, consequently, too expensive;

It is for these reasons that the former Est Railway System undertook laboratory experiments, side by side with investigations into sound-proofing of stock, properly so called.

SECOND PART.

LABORATORY INVESTIGATIONS.

Having reduced the production of noise as much as possible, residual noises must be prevented from propagating themselves; to achieve this is the object of the laboratory investigations.

These consist of:

(*a*) study of the transmission of noise through air;

(*b*) study of its transmission through solids.

I. — Transmission of noise.

Noise produced by some external source penetrates in different ways into the interior of a vehicle. The transmission can in fact occur:

(*a*) through either the walls or compartment partitions,

(*b*) through the windows, or

(*c*) through openings.

No purpose would be served by increasing the isolating properties of a compartment wall or window if, during assembly, one failed to carefully seal up every opening or crack there might happen to be; the influence of the latter is investigated elsewhere at the end of this chapter. Investigation into transmission qualities must therefore be made under conditions of absolute tightness.

1. Experimental apparatus.

Every acoustic investigation necessarily pre-supposes the absence of noises having nothing to do with it and liable to interfere with the taking of measurements. It is difficult to obtain satisfactory conditions for making such measurements in towns, even if the work can be done during periods of relative quiet, at night for example. Every test room, moreover, has a measurement or recording room adjacent to it and a small fitting shop, from which interfering noises are liable to come. In addition any ordinary type of test room is difficult to adapt to acoustic investigations, owing to more or less re-echoing always present and its large number of resonant frequencies which give rise to stationary waves producing considerable interference with any measurement work, especially in the case of pure sounds. It was therefore necessary to

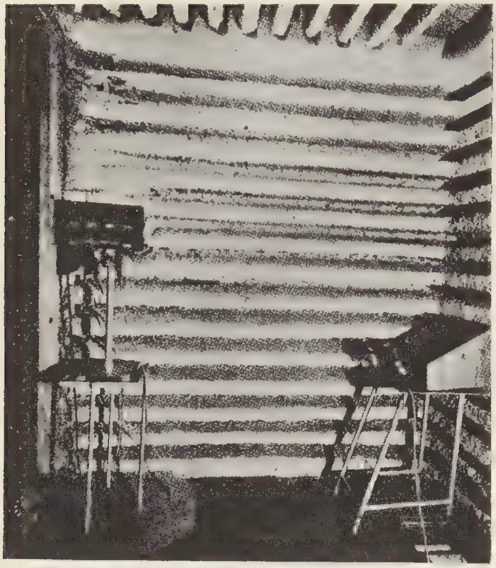


Fig. 4.

find, or have made, a test room especially arranged for these investigations. The « Compagnie Parisienne de Distribution d'Electricité », which had previously had such a test room built (1), put it at our complete disposal.

This room measures 4.60 m. × 2.60 m. × 2.30 m. (15'1" × 8'6 3/8" × 7'6 9/16"), and is well insulated against external sounds; it is formed of two concrete casings, one inside the other and having no points of contact between them save that provided by four springs between the floors. The interior casing standing on its springs has a natural frequency of two seconds, which obviates the transmission of noise through the ground. The walls have a thickness of from 15 to 22 mm. (19/32" to 7/8") and are separated by an air space. Stationary waves are reduced by the two following methods :

(1) See *Revue Générale de l'Electricité* for January 30th, 1937 : « La Salle Muette de la C. P. D. E. » (The C. P. D. E's silent test room), by P. BARON.

(*a*) the walls and ceiling are shaped like saw teeth;

(*b*) the walls are covered with absorbent material and the floor with a thick carpet.

In order to measure the diminution produced in sounds by passing through partitions, the so-called deaf room is divided into two portions by a removable frame carrying the test partition. In one of the half-rooms so formed (fig. 4) is placed the loud speaker, actuated by a heterodyne set producing pure modulated sounds; in the other half-room the microphone of a sonometer is placed which measures the mean pressure of the sound p_1 when the partition is not mounted and of the sound p_2 when it is.

For convenience in fitting up, the test panel, measuring 2.24 m. × 2 m. (7' 4 3/16" × 6' 6 3/4") has had to be mounted in two pieces; the test measurements are thus made on two partitions measuring 2.24 m. × 1 m. (7' 4 3/16" × 3' 3 3/8"), sizes approaching those of the panels and partitions of the carriages. The movable frame is formed by angles and ash frame pieces which grip the test panel plates by a locking device in order to obtain a *constant fit* and a *good tightness* (the frames are covered with pulverised textile material).

2. Method of measurement employed.

Measurements of sound pressures are taken at twelve different points, the average measurement giving the average pressure of the field of sound obtaining in the room.

If p_1 = the average pressure when the partition is not mounted, p_2 when it is, the weakening effect R of the partition, expressed in decibels, is :

$$R = 20 \log_{10} \frac{p_2}{p_1}.$$

If p_0 = 0.207 millibarye is the fringe of audibility,

$$R = 20 \log_{10} \frac{p_1}{p_0} - 20 \log \frac{p_2}{p_0}.$$

The reduction R is thus equal to the diffe-

rence between the readings in decibels indicated by the sonometer in the two cases.

The measurements are carried out at the following frequencies :

50 p.p.s.	pure sound	
90 to 150 p.p.s.	modulated sound	
225 to 300 p.p.s.	do.	do.
480 to 600 p.p.s.	do.	do.
925 to 1 175 p.p.s.	do.	do.
1 970 to 2 200 p.p.s.	do.	do.
2 700 to 3 000 p.p.s.	do.	do.

3. Tests.

Investigations were carried out regarding :

(*a*) transmission of sound through metal partitions;

(*b*) transmission of sound through windows.

(a) Transmission of sound through metal partitions.

Investigations were undertaken systematically with :

— for partitions in one material only:

1. A single partition;
2. A double partition formed of two plain walls and an air space.

— for partitions of more than one material :

3. A single partition having one face covered with some light material;
4. A double partition formed of two walls, the inside faces being covered with some light, thin material;

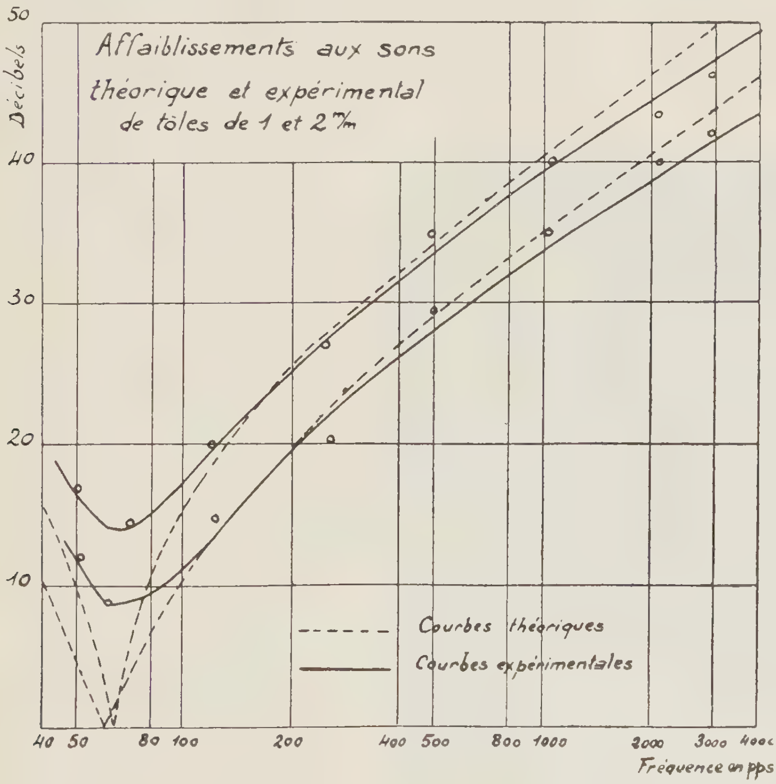


Fig. 5.

Explanation of French terms:

Affaiblissements aux sons... = theoretical and experimental diminutions of sounds for plates of 1 and 2 mm. (0.039 and 0.078 in.) thickness. — Courbes théoriques (expérimentales) = theoretical (experimental) curves. — Fréquence en pps. = frequency in periods per second.

5. A double partition, the space between the walls being filled with some « insulating » material.

1. *Single partition of one material only.* — The experiments were made with steel and aluminium plates, the thickness varying from 1 to 2 mm. (0.039 to 0.078 in.).

Before giving the results of readings obtained it appears useful to give an outline of the theory of the transmission of sound through thin sheet material. A theoretical exposition of this question is very difficult, if it is desired to take into account the numerous resonant frequencies produced in the plates by any particular source of sound.

The following numbers of resonant frequencies have been observed with the steel plates used :

(*a*) 1-mm. plate. — 58 resonant frequencies, from 25 to 2 000 p. p. s.

Fig. 6.

(*b*) 2- mm. plate. — 89 resonant frequencies, from 35 to 4 000 p. p. s.

However, of all these frequencies the fundamental one, f_0, is by far the most important and will be the only one employed in the calculations which follow.

If we assume :—

— the plate to be plane and of infinite size;

— the sound waves to be plane and of normal incidence;

— the plate to be rigid, with a mass σ per unit of surface and of small thickness,

the diminution in the sound R due to the plate is given, according to Rayleigh's theory of thin walls, by the expression :

$$R = 20 \log_{10} \left[\frac{\pi \sigma}{\rho c}\left(f - \frac{f_0^2}{f}\right)\right] \quad . \quad . \quad . \quad . \quad (1)$$

in which ρ and c are respectively the density of the air and the velocity of sound in the air.

For frequencies markedly higher than the fundamental one, above 100 p.p.s. for example, $\frac{f_0^2}{f}$ is small relatively to f, and R takes the form :

$$R = 20 \log_{10} \frac{\pi \sigma}{\rho c} + 20 \log f \quad . \quad . \quad . \quad (2)$$

If, therefore, a curve is traced, with R as ordinate expressed in decibels and log f as abscissa, a straight line is obtained (fig. 5).

If R_1 is the diminution corresponding to a sheet of thickness e, R_2 that corresponding to one of thickness $2e$ then, for frequencies removed from that of resonance :

$$R_2 = 20 \log_{10} \frac{2 \pi \sigma}{\rho c} + 20 \log f =$$
$$= R_1 + 20 \log_{10} 2 = R_1 + 6 \text{ dbl.}$$

R_1 and R_2 are thus represented by two straight lines separated by 6 dbl.

The diminution R is therefore proportional to the logarithm of the mass and that of the frequency; it follows that the process of sound-insulating railway

carriage compartments becomes all the more difficult as :

1. The compartment walls have to be kept thin; (doubling their weight, which would be an enormous increase, only gives an improvement of 6 dbl).

2. The sound spectrum is principally composed of notes of low frequency, for which the diminution of the sound is small.

According to formula (1), a knowledge of f_0 allows of calculating R as a function of f, since the values of σ, ρ, and c are known. It is therefore necessary to determine f_0; this is done with the aid of a small coil fixed to the centre of the plate, set vibrating by the sound, and moving in the magnetic field of a fixed coil. The alternate difference of potential so produced is amplified and recorded by an oscillograph (fig. 6). The maximum recorded amplitude allows of the resonant frequency f_0 being arived at. We have ascertained that :—

for a steel sheet of :

2.24 m. × 1 m. (7' 4 3/16" × 3' 3 3/8"), 1 mm. (0.039") thick, $f_0 = 63$ p.p.s.

2.24 m. × 1 m. (7' 4 3/16" × 3' 3 3/8"), 2 mm. (0.078") thick, $f_0 = 68$ p.p.s.

In Table I below are shown the test results obtained with plain steel and aluminium sheets [the numbers in brackets being those given by Formula (1)].

Doubling the thickness of the sheet only gives, by experiment, an average increase of 5 dbl., at high frequencies, while Formula (2) showed it would be 6 dbl., a satisfactory measure of agreement.

For the fundamental resonance frequency f_0, R is nil according to (1) — experimentally, however, it is not — the effect of damping having been left out of the calculations; if it is taken account of, s being the co-efficient of damping, we have :—

$$R = 10 \log_{10}\left[\frac{\pi^2 \sigma^2}{\rho^2 c^2}\left(f - \frac{f_0^2}{f}\right)^2 + \left(1 + \frac{s}{2 \rho c}\right)^2\right] \quad (3)$$

at the resonant frequency $f = f_0$, we have

$$R = 20 \log \left[1 + \frac{s}{2 \rho c}\right] \quad . \quad . \quad (3a)$$

Knowing R by experiment, we can deduce s from it. Actually for the steel sheet

1 mm. thick, $R_1 = 8.5$ dbl and $s_1 = 155$
2 mm. thick, $R_2 = 12$ dbl and $s_2 = 340$.

2. *Double partition formed of two plain walls plain and an air space.* — The partition is formed of two sheets, 1 mm. and 2 mm. thick, separated by a space d of 50 to 80 mm. (2" to 3 1/8"), (corresponding to the present limits of the double walls of carriages).

If Rayleigh's theory is applied with the same hypotheses as for the single sheet,

TABLE I.

Nature and thickness of plates.	Weight, kgr./m² *(lb./sq.ft.)*.	Value of the diminution R in decibels, with the experimental frequencies in periods per second.						
		50	90-150	225-300	480-600	925-1175	1970-2200	2700-3000
Steel, 1 mm. . *(0.039")*	7.8 *(1.6)*	11.5 (4.5)	14.5 (13)	20 (22)	29.5 (28.5)	34.5 (35)	40 (41)	42 (43.5)
Steel, 2 mm. . *(0.078")*	15.8 *(3.24)*	17 (10.5)	20 (19)	27 (28)	35 (34.5)	40 (41)	43.5 (47)	46.5 (49.5)
Aluminium, 1 mm. . . .	2.6 *(5.32)*	5 (3)	5 (5)	13 (12.5)	17 (19)	22 (26)	28 (30)	32 (34)
Aluminium, 2 mm. . . .	5.2 *(10.65)*	8 (6)	9 (11)	16 (18.5)	23 (25)	28 (32)	33 (36)	37 (40)

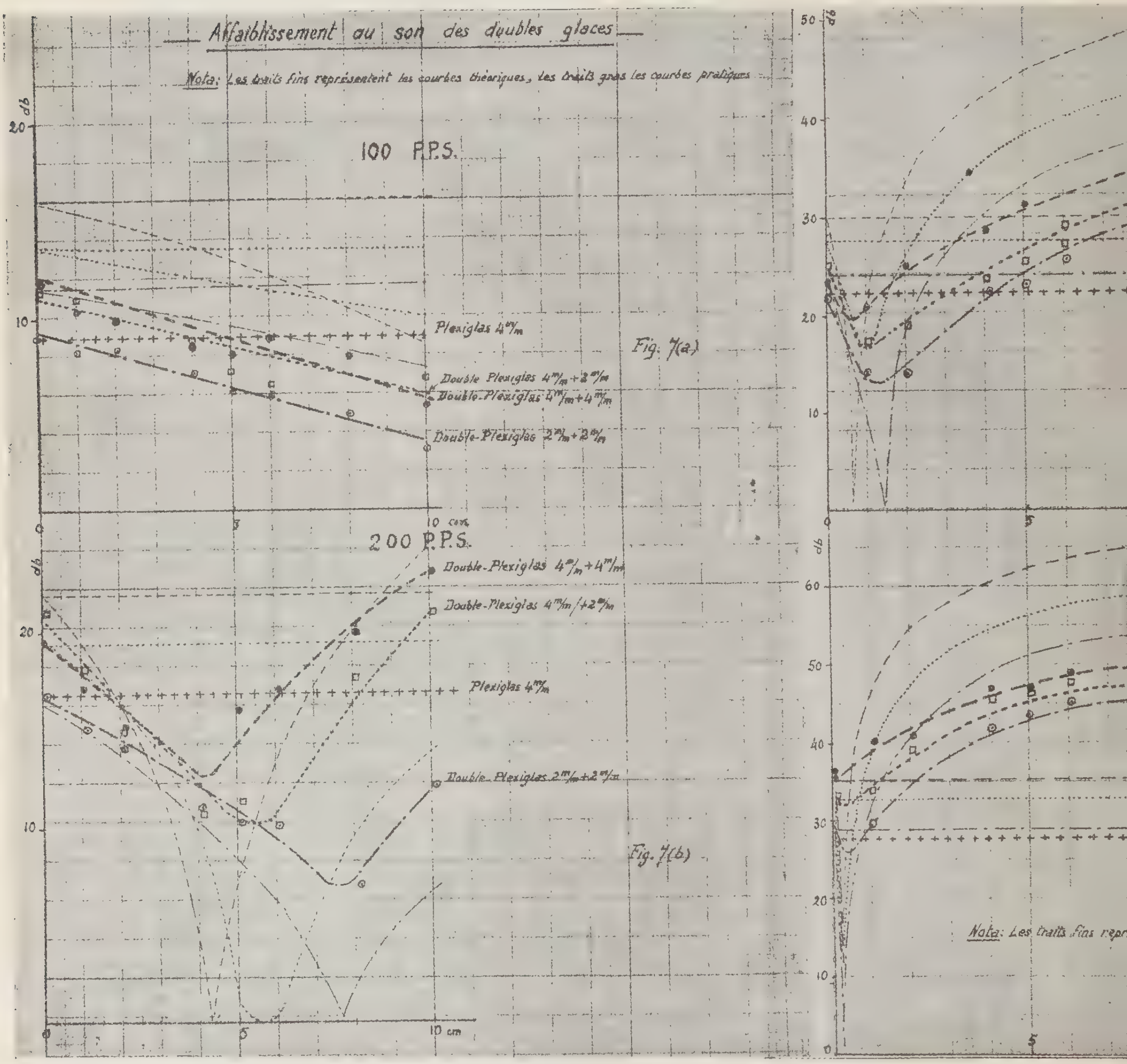
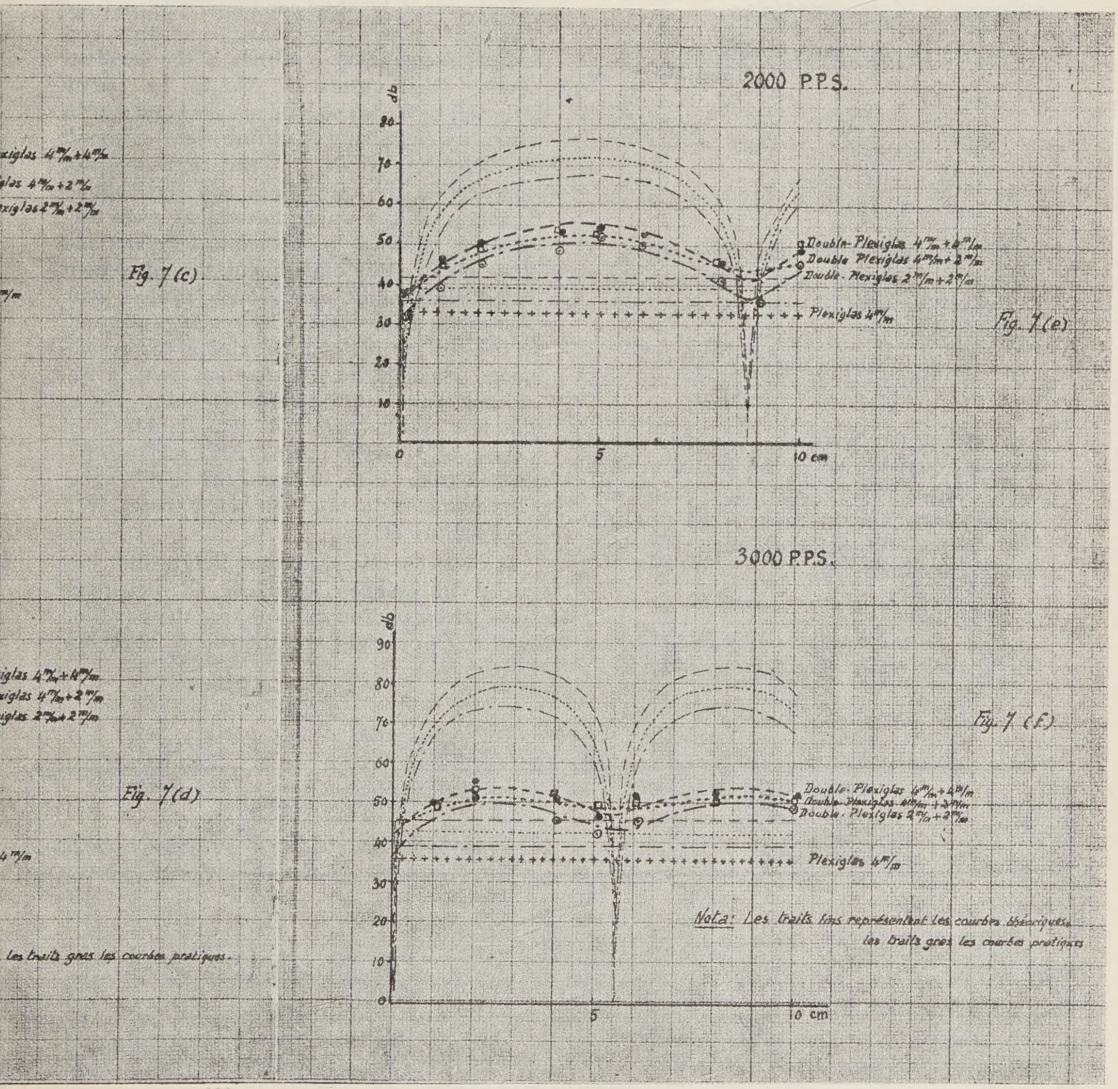


Fig. 7. — Diminution

Note. — Thin lines represent theoretical



ouble-glass windows.

epresent those obtaining in practice.

σ_1 and σ_2 being respective masses per unit of surface of each sheet, the diminution of the sound R with the double partition for a pulsation ω of the sound is :—

$$R = 10 \log_{10} \left| 1 + \omega^2 \left[\frac{\sigma_1^2 + \sigma_2^2}{4 \rho^2 c^2} + \right. \right.$$

$$\left. + \frac{\sigma_1^2 \sigma_2^2}{8^4 c^4} \omega^2 - \frac{\sigma_1 \sigma_2}{2 \rho^2 c^2} \cdot \frac{\sigma_1 + \sigma_2}{2 \rho c} \omega \sin \frac{2 \omega d}{c} \right.$$

$$\left. \left. - \frac{\sigma_1 \sigma_2}{2 \rho^2 c^2} \left(\frac{\sigma_1 \sigma_2}{4 \rho^2 c^2} \omega^2 - 1 \right) \cos \frac{2 \omega d}{c} \right] \right| . \quad (4)$$

R is therefore a function of ω and d.

(*a*) If ω is constant and d variable (fig. 7), R passes through a series of maxima and minima such that:

$$\tan 2 \frac{\omega d}{c} = \frac{2 (\sigma_1 + \sigma_2)}{4 - \sigma_1 \sigma_2};$$

(*b*) If d is constant and ω variable (fig. 8), a value equal to that of the partition, which R at first assumes for the small values of ω has the same mass as that of the two adjacent sheets, and passes through a series of maxima such that :—

$$\tan \frac{\omega d}{c} = \frac{\rho c}{\omega r} \cdot \frac{\sigma_1 + \sigma_2}{\sigma_1 \sigma_2}$$

an equation easily solved graphically.

It has been assumed in these calculations that the incident waves were normal to the partition.

Unfortunately this condition can not be attained under experimental conditions and it must be pointed out that if the incident sound were normal it would be partly reflected towards the loud speaker and would affect its emission. A diffuse field of sound has been created and, in practice, it does not appear that the divergence and the oblique incidence of the waves introduces great differences between the theoretical results and those obtained by experiment, the agreement being sufficiently close for a simple wall. The method for taking the readings did not, moreover, permit of determining the resonances, as could have been done with a recording device (1). Table II below shows the test results obtained with double steel panels of 1 and 2 mm. (0.039" and 0.078"), spaced from 50 to 100 mm. (2" to 4") apart [the numbers in brackets being those given by Formula (4)].

It may be observed that the results obtained in practice approach all the more those given by Formula (4) that the partition is of lighter weight and the sound frequency lower.

TABLE II.

Nature of plates.	Weight, kgr./m² *(lb./sq. ft.)*	Air space mm. *(in.)*	Value of the diminution R, in decibels, with the experimental frequencies in periods per second.						
			50	90-150	225-300	480-600	925-1175	1970-2200	2700-3000
Steel, 1 and 2 mm. . . *(0.039" and 0.078")*	23.4 *(4.8)*	50 (2")	16 (16)	19 (18)	32 (43)	38 (58)	45 (72)	47 (88)	50 (90)
		100 (4")	17 (10)	20 (10)	33 (42)	39 (64)	48 (82)	49 (87)	51 (96)
Aluminium, 1 and 2 mm.	7.8 *(1.6)*	50 (2")	7 (11)	7 (13)	11.5 (9)	25 (46)	49 (64)	52 (78)	50 (76)
		100 (4")	7 (8)	8 (8.5)	21 (24)	33 (51)	49 (66)	50 (72)	52 (82)

(1) The latter method was employed for investigating transmission through window glasses.

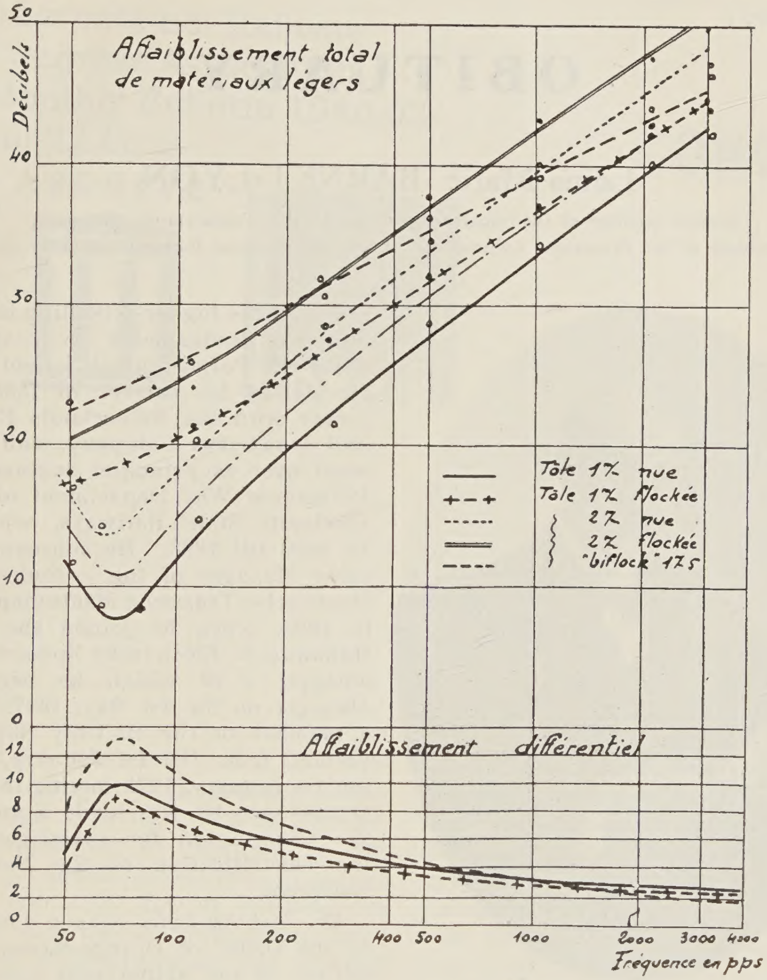


Fig. 8.

Explanation of French terms:

Affaiblissement total... = total diminution with light-weight materials. — Affaiblissement différentiel = differential diminution. — Fréquence en p. p. s. = frequency, in p. p. s.

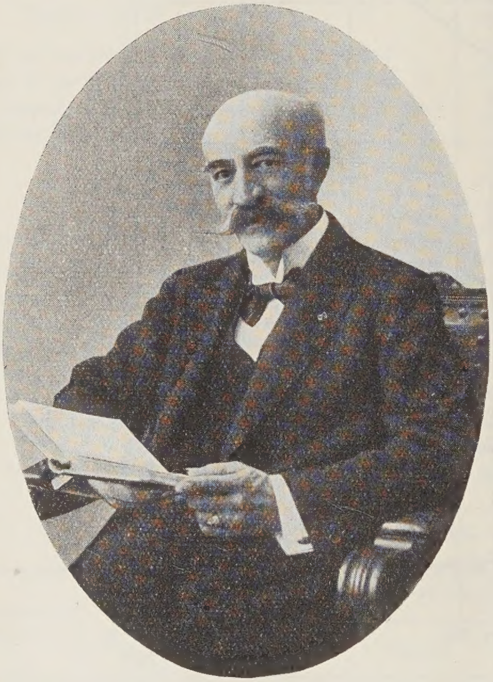
——— 0.039 in. plain plate.
+—+ 0.039 in. plate, flock treated.
..... 0.078 in. plain plate.
═══ 0.078 in. plate, flock treated.
- - - - « biflock » 175 plate.

(To be continued.)

OBITUARY

Louis-Marie BARNET-LYON,

Former Member of the Supervisory Council of the Netherlands Railways,
Former Member of the Permanent Commission of the International Railway Congress Association.



We heard with deep regret of the death, on the 20th November, 1939, of Mr. Louis-Marie BARNET-LYON, Civil Engineer, former member of the Supervisory Council of the Netherlands Railways and former member of the Permanent Commission of our Association.

Mr. BARNET-LYON was born in Brussels, on the 5th December, 1862. He received his higher schooling in Holland and was graduaded a civil engineer at the Delft Polytechnical School in 1887. He started his carreer in 1888, as engineer with the Netherlands Electricity and Ironworks Company, and in 1891 went over as principal engineer to the Permanent Way Department of the Netherlands State Railways, which post he held till 1898. He subsequently became Manager of the « Nederlandsche Electrische Tramweg Maatschappij », up to 1905, when he joined the « Zuid-Hollandsche Electrische Spoorweg Maatschappij » of which he became the Manager on the 1st May, 1907. He was a member of the Railway Supervisory Council from the 1st January, 1913, to the 1st January, 1922; owing to his high competence he was made a member of the Commission for investigation into the electrification of the Netherlands Railways.

Mr. BARNET-LYON was a Commander of the Order of Orange-Nassau and an Officer of the Netherlands Lion.

He was appointed as member of the Permanent Commission of our Association in 1922. Despite his many occupations, he always took a personal interest in our work; he attended the Rome (1922) and London (1925) Congresses. He resigned his membership in 1925.

We wish to convey our heartfelt sympathy to his family.

The Executive Committee.